Co-firing of solid and liquid biomass performed on boiler OP-130 in PCC Rokita SA - comparison of effects on operational parameters and cost

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Co-firing tests PC boiler Op-130t/hr:

- Co-firing tests - with 10 and 36% share of wooden and seed rape biomass respectively with various combinations of blend biomass with coal dust feeding
- Co-firing coal dust with glycerol with and without urea addition - in proportion ~ 30 % by mass using special burners located close to two corner Goals:
  - assessment the required technical and operational parameters of co-firing of biomass in utility boilers as well as the effect of solid and liquid biomass on boilers parameters behavior
  - assessment of the impact of biomass on emissions and the risk of fouling and slagging
The tests of co-firing with high share of rapeseed - biomass and liquid – glycerin was performed in the PCC Rokita SA - Brzeg Dolny on boiler K8 OP-130 with the 80% of nominal output of steam,

This boiler is integrated into CHP unit, the scheme of this unit is presented in figure on next slide,

Biomass in the form of rapeseed meal - the rape waste was used in the co-firing test and liquid raw glycerin

The tested boiler of 130 t/h live steam (thermal output 100 MW$_{th}$) was operating at stable conditions at the characteristic load i.e. 80% of the nominal parameters. The nominal temperature of reheat steam was kept .

The effect of co-firing on operational boilers parameters was investigated: steam parameters and output; burnout, emission, co-milling performance, fouling.

Additionally distribution of temperature in combustion chamber in cross section at 14,5 m level i.e. above burner were measured by suction pyrometry.
The scheme of CHP with OP-130 boiler (named K-8)
The program of the test for co-firing with solid biomass:

- The effect of biomass on milling-the analyses of particle size distribution after the mills for reference case and for blend biomass- pulverized coal,

- The burnout during co-firing-the analysis of burnout after the boiler,

- The effect of biomass on emission - the investigation of emission NOx, SO2,

- The effect of contribution of biomass on distribution temperature in combustion chamber - the comparison temperature distribution in cross section of combustion chamber above the burners for reference case and co-firing,

- The comparison of operational boiler parameters for both tests
Actions:

- reference test with dust coal - this fuel was feed by the 8 burners located on the second and third level.
- co-firing test blend of biomass with coal was feed through 4 burners on the first level (biomass share by mass in this level was 60,65%) and the coal dust has been supplied through 4 burners in second level. This configuration of burners and biomass dosage was adopted based on analysis of preliminary tests.
- During the reference tests conducted at a load of the boiler 80% of the amount of dispensed coal dust to the boiler was 12 t/hr.
- at co-firing the mass flux of dust coal was 6 t/hr feed into second level of burners and blend of 3,2 t/hr of coal dust with 5 t/hr of rape waste into first level of burners.
- Thus total weight share of biomass in blend was 35%.
- The blends was prepared outside of transporting system and next was transported to day bin at the boiler by tape conveyor, And next this mixture was supplied from the day bin to the modified fan mills.
- In the variant with rape waste co-firing the thermal share attains 29,84%.
System dosing of biomass
Biomass share (by mass) ~36%

Blend of biomass with coal was feed through 4 burners on the first level (biomass share by mass in this level was 60.65%) and the coal dust has been supplied through 4 burners in second level. This configuration of burners and biomass dosage was adopted based on analysis of preliminary tests.
# Fuel Characteristic

<table>
<thead>
<tr>
<th>Fuel</th>
<th>M as received</th>
<th>M$^a$</th>
<th>A$^a$</th>
<th>A$^d$</th>
<th>VM$^a$</th>
<th>VM$^{daf}$</th>
<th>HCV</th>
<th>LCV</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>MJ/kg</td>
<td>MJ/kg</td>
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<td>Hard Coal-Rokita</td>
<td>5</td>
<td>2.22</td>
<td>22.68</td>
<td>23.19</td>
<td>25.98</td>
<td>34.59</td>
<td>24.54</td>
<td>23.78</td>
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<tr>
<td>Rape Waste Rokita</td>
<td>17</td>
<td>1.24</td>
<td>7.30</td>
<td>7.39</td>
<td>69.13</td>
<td>75.59</td>
<td>19.522</td>
<td>18.21</td>
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<table>
<thead>
<tr>
<th>Fuel</th>
<th>C$^{daf}$</th>
<th>H$^{daf}$</th>
<th>N$^{daf}$</th>
<th>S$^{daf}$</th>
<th>O$^{daf}$</th>
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<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
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<td>Hard Coal-Rokita</td>
<td>87.0439</td>
<td>4.9534</td>
<td>1.84</td>
<td>0.1332</td>
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<td>Rape Waste Rokita</td>
<td>50.6451</td>
<td>6.69145</td>
<td>6.55</td>
<td>0.208</td>
<td>35.9</td>
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Size distribution

AFTER 1st MILL-total mass fraction of coal dust smaller than $\delta_i$

AFTER 2nd MILL-total mass fraction of coal dust smaller than $\delta_i$

AFTER 3rd MILL-total mass fraction of coal dust smaller than $\delta_i$

AFTER 1st MILL-total mass fraction of blend (rape seed 60.64%) dust smaller than $\delta_i$
### Characteristic of ash

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>co-firing 35% RAPE + 65% H.C. bottom ash, %</th>
<th>co-firing 35% RAPE + 65% H.C. fly ash</th>
<th>coal combustion bottom ash, %</th>
<th>coal combustion fly ash, %</th>
<th>ash from rapeseed meal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashing temp</td>
<td>(600 °C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SiO₂ and insoluble part</td>
<td>77.37</td>
<td>79.05</td>
<td>79.34</td>
<td>65.80</td>
<td>64.06</td>
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<tr>
<td>Al₂O₃</td>
<td>10.77</td>
<td>3.99</td>
<td>10.96</td>
<td>20.37</td>
<td>0.02</td>
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<td>Fe₂O₃</td>
<td>5.62</td>
<td>10.58</td>
<td>5.15</td>
<td>6.57</td>
<td>0.48</td>
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<td>Mn₃O₄</td>
<td>0.07</td>
<td>0.14</td>
<td>0.07</td>
<td>0.11</td>
<td>0.12</td>
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<td>TiO₂</td>
<td>1.35</td>
<td>1.27</td>
<td>1.37</td>
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<td>CaO</td>
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<td>2.39</td>
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<td>MgO</td>
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<td>0.33</td>
<td>0.20</td>
<td>1.02</td>
<td>6.86</td>
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<td>Na₂O</td>
<td>0.97</td>
<td>1.41</td>
<td>0.40</td>
<td>0.07</td>
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<td>K₂O</td>
<td>2.84</td>
<td>0.79</td>
<td>1.79</td>
<td>1.57</td>
<td>23.55</td>
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<td>SO₃</td>
<td>0.07</td>
<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
<td>0.15</td>
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<tr>
<td>slag index</td>
<td>0.12</td>
<td>0.18</td>
<td>0.09</td>
<td>0.14</td>
<td>0.55</td>
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<tr>
<td>fouling factor</td>
<td>0.44</td>
<td>0.40</td>
<td>0.20</td>
<td>0.22</td>
<td>13.26</td>
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<tr>
<td>slag viscosity</td>
<td>92.11</td>
<td>85.59</td>
<td>92.88</td>
<td>86.44</td>
<td>85.18</td>
</tr>
</tbody>
</table>

### Trace elements in biomass materials (mg/kg)

<table>
<thead>
<tr>
<th>Biomass type</th>
<th>Cd</th>
<th>Zn</th>
<th>Cu</th>
<th>Ni</th>
<th>Cr</th>
<th>Pb</th>
<th>Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rape straw</td>
<td>0.65</td>
<td>7.93</td>
<td>2.91</td>
<td>3.95</td>
<td>0.44</td>
<td>0.96</td>
<td>&lt;0.03</td>
</tr>
</tbody>
</table>
The view of mixture of rape waste with hard coal inside of fan-mill number 3 and 1.

Mixture after grinding in fan mill.
Temperature distribution

OP-130 level 14,5 m
Coal

Op-130 level 14,5 m
65% coal + 35% rapeseed meal

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The dust emissions at cofiring did not change significantly, especially dust emission was rather stable. However, the NOx emission noticeably lowered; NOx emission drop from 500mg/m3 to 300mg/m3 in spite of the high content of nitrogen in biomass but the small increases of SO2 emission was observed.

Feeding of biomass above dust coal burners results higher temperature in cross section of combustion chamber compare with only coal dust combustion what is visible in previous slide. The high content of volatile matter of biomass and high reactivity results good mixing in volume of combustion chamber of hot flue gas and causes more uniform distribution of temperature in furnace and probably occurrence of reburning reactions. This results can be improved by improving of burners outlet and milling.

**Graphs:**

- **Graph 1:** Emission
  - X-axis: Time
  - Y-axis: Concentration at 6% O2, mg/Nm3
  - Data points for Hard coal, Hard coal + rape waste

- **Graph 2:** Emission
  - X-axis: Time
  - Y-axis: Concentration at 6% O2, ppm
  - Data points for Hard coal, Hard coal + rape waste
Co-firing rapeseed meal with coal at high share 36% by mass improve some parameters compare to reference case i.e during combustion of coal dust:

- The operational parameters were kept stable,
- Grinding of blend slightly worsed milling but in rape seed problems with separation of biomass in fan mill doesn’t observed.
- Decrease of NOx emission above 30%
- Decrease of unburned parts especially in fly ash (50%) and no problems with fouling and slagging
- Not observed effect of co-firing of biomass on electrostatic precipitator (EP) and desulphurization system
- The supply of biomass through the first level of burners and dust coal through second level of burners appeared more favorable taking into account the rate of burnout and the boiler capacity.
Co-firing tests with glycerine

Boiler operation: Co-generation of steam and electricity (100MWth, 8MWe)

Boiler capacity - 65% nominal output
Coal feeding – 4.5t/h
Bioliquid feeding – 3t/h (40% by wt.)

Boiler efficiency: 83-85 %
Co-firing tests with glycerine

Scheme of the OP-130 boiler (right side view).

Gas dynamic burner in operation.
Co-firing tests with glycerine

Characteristics of particle size distribution of coal dust from Rokita unit.

- Total mass share of particles smaller than $\delta_i$%
- 1st Level
- 2nd Level
- 3rd Level

Size distribution of the dust in CHP.

Hard coal feeding variants.

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Co-firing results

**Fig. 17. Emission of gaseous impurities during co-firing tests, CHP boiler.**

The positive effect visible after test.
- Stable steam parameters,
- Burnout slightly drop 0.3%,
- ~NOx reduction from 600mg/m3 to 400mg/m3
Introduction

**Variant 1. hard coal**

**Variant 1. hard coal + glycerine**

Fig. 13. Temperature distribution inside the combustion chamber

Fig. 14. Temperature distribution inside the combustion chamber, V1 H.C. + G.

More uniform temperature reburning reactions in variant 1
The analysis of burnout show slightly lower burnout about 0.3%.

The ash of glycerine contains significant amount of potassium, however in bottom and fly ash collected during tests of co-firing the potassium increases about 1%.
co-firing in the PC boiler 100MWth with two liquid burners, CHP

Boiler capacity – 75% nominal output
Coal feeding – 5,2 t/h
Glycerine feeding – 3,5 t/h (40% by wt.)

Glycerine burners

the combustion chamber
Co-firing in the PC boiler-100MWth, CHP

Results – temperature distribution

Variant 1. hard coal

Variant 2. hard coal + glycerine

Fig. 13. Temperature distribution inside the combustion chamber, V2 H.C. + G

Fig. 14. Temperature distribution inside the combustion chamber, V1 H.C. + G.
The sodium and potassium was observed mostly in the fly ash.
Co-firing in the PC boiler 100MWth, CHP

more uniform temperature
Reburning reactions in variant 1 occurrence
NOx reduction from 220ppm to 145ppm
Conclusion

- Lower ash emission (coal consumption lower than results from heat balance)
- Decrease the burnout
- Uniform temperature distribution
- Stable operating parameters
- Decrease NOx emission, (reburning reaction)
- K2O content in fly ash is higher for variant 2 + Glycerine Most of potassium compounds are present in the fly ash
- SO2 Increase significantly
Thank you for your attention.

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